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AUTHOR Wasil, Ed: Espy John
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ABSTRACT

This fifth in a series of eight modules for a course titled Mechanical Inspection describes cleaning activities which typically apply to construction, maintenance, and modification activities at the nuclear power plant site. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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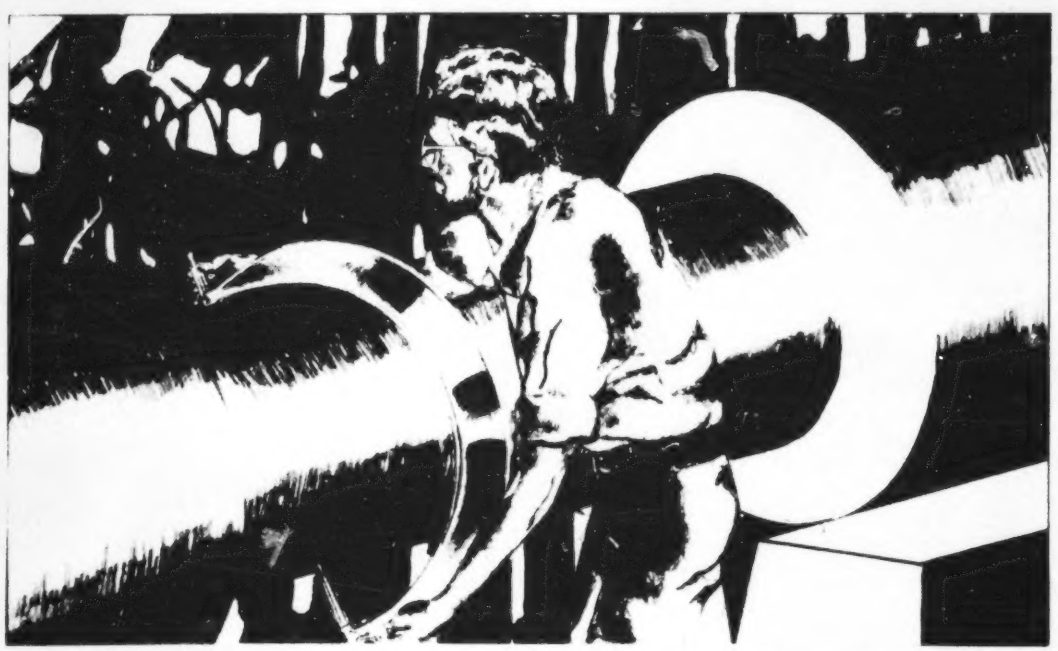
NUCLEAR TECHNOLOGY

COURSE 30 MECHANICAL INSPECTION

MODULE 30-5 Surface Cleaning Inspection



CE 024 281

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 30 MECHANICAL INSPECTION

Module 30-1	Pump Inspection
Module 30-2	Pump Functional Testing
Module 30-3	Valve Inspection
Module 30-4	Piping Inspection
Module 30-5	Surface Cleaning Inspection
Module 30-6	Protective Coating Inspection
Module 30-7	Pressure Vessel Inspection
Module 30-8	Rotating Equipment Inspection

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This module was prepared for General Physics Corporation by Ed Wasil and John Espy, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

INTRODUCTION

The Nuclear QA/QC Technician normally has responsibility for inspecting product for cleanness and for monitoring plant activities for compliance with procedures pertaining to housekeeping and cleaning operations. The Technician may also audit the cleaning operations of contractors and suppliers.

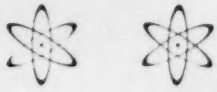
Reactor systems and balance of plant systems require various levels of cleanness dependent upon the functions of the particular system. Requirements for cleanness principally stem from three concerns: (1) minimizing the introduction of soils which become radioactive during nuclear power plant operation, (2) avoiding the introduction of soils which interfere with system operation or shorten component life-time by accelerating corrosion or wear, and (3) avoiding the introduction of soils which may plug flow passages.

Cleanness requirements begin with the material suppliers and extend through component manufacture and plant construction, maintenance and modification. At each of these phases of product life, the soils introduced by the work activities may vary considerably. For example, steel mills may be mostly concerned with removing heavy oxide scales or sand (silica) inclusion on surfaces. Manufacturers may be mostly concerned with removing machining and cutting oils. Constructors may be mostly concerned with removing welding fluxes and light oxide films. While there are a number of cleaning methods available, the cleaning method selected for use must be capable of cleaning the types of soils encountered.

This module initially describes cleaning methods and their capabilities. Regardless of where these cleaning methods may be used, the student/trainee will recognize the principle elements of each cleaning process and its

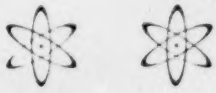
general use. The module then describes cleaning activities which typically apply to construction, maintenance, and modification activities at the nuclear power plant site. It is at the power plant site that the majority of duties of the Nuclear QA/QC Technician are performed.

A glossary of terms is given at the end of the module. The student/trainee should refer to the glossary as new terms are encountered.



MODULE PREREQUISITES

There are no prerequisites for this module.



OBJECTIVES

Upon completion of this module, the student/trainee can:

1. Define the terms: cleaning, contamination, crevice, dead leg, flushing, inaccessible area, and layup.
2. Briefly describe the cleaning process and types of soils removed for any of the cleaning methods of solvent, emulsion, acid, chelating, vapor degreasing, abrasive blasting, salt bath descaling, and alkaline.
3. Name four cleanness classification levels, briefly describe the degree of cleanness associated with each level, and associate types of components or systems with their normal cleanness classification.
4. Given any of the following cleanness control activities: cleanness classification, preinstallation cleanness,

installation cleaning, maintenance of installation cleanness, preoperational cleaning, layup, and housekeeping. State the purpose of the activity and briefly describe how it is accomplished.

5. Describe typical preparations for flushing which are associated with any of the following topics: other plant activities, personnel readiness, circulating flow paths, component protection, and water quality.
6. Describe typical water treatment for wet layup.
7. Demonstrate ability to visually inspect components for compliance with specified cleanness requirements.

NOTES TO INSTRUCTOR / STUDENT

Three activities are included in this module. The first consists of word descriptions of product from which the student/trainee must determine acceptability of cleanness and, if unacceptable, specify an adequate cleaning method. Actual product, if available, should be substituted for the word descriptions. The other two activities are considered optional. These would require the student/trainee to perform a Jackson Turbidity and a Titration.

SPECIFIC CLEANING METHODS

Eight Methods

Two primary factors govern the selection of the specific cleaning method. These factors are the type of soil encountered and the effect of the cleaning operation on the product. Sometimes, more than one method is necessary to remove all soils encountered for given product. Eight cleaning methods are common: solvent cleaning, emulsion cleaning, acid cleaning, acid pickling, chelating, vapor degreasing, abrasive blasting, salt bath descaling, and alkaline cleaning.

The eight cleaning methods are used primarily by component and materials suppliers to clean items prior to delivery to the nuclear power plant construction site. Construction activities attempt to maintain cleanness of the items from receipt through installation. But when construction activities introduce soils, an appropriate cleaning method is selected to reclean the item.

Solvent Cleaning

Solvent cleaning is a process for removing organic soils from the surfaces of components by the use of organic solvents. The most common organic solvents in use are aliphatic petroleums, chlorinated hydrocarbons, or blends of these two classes of solvents. Table 30-5-1 lists the commonly used solvents.

Of the solvents listed in Table 30-5-1, Stoddard solvent and mineral spirits are the most widely used due to their low cost and comparatively high flash points. The chlorinated hydrocarbons are excellent solvents and are nonflammable but are more toxic than the aliphatic petroleums. In many cases, mineral spirits is mixed with 25 to 50% of a

Table 30-5-1. Cleaning Solvents

Solvent	Flash Point, F(a)	Toxicity, ppm(b)
Aliphatic Petroleums		
Kerosene	145	....
Naphtha, hi-flash	110	....
Mineral spirits	57	500
Naphtha, VM&P	48	500
Stoddard solvent	105	500
Chlorinated Hydrocarbons		
Chloroform	None	50
Methylene chloride	None	500
Perchlorethylene	None	100
Trichloroethane (1,1,1)	None	500
Trichlorethylene	None	100
Trichlorotrifluoroethane	None	1000
Alcohols		
Ethanol, SD	57	1000
Isopropanol	50	400
Methanol	54	200
Other Solvents		
Acetone	0	1000
Benzol	12	25
Cellosolve (c)	104	200
Toluol	40	200

(a) Tag closed cup. (b) Threshold limit values, adopted at 1962 meeting of American Conference of Governmental Industrial Hygienists, expressed as parts of vapor or gas per million parts of air by volume at 25 C and 760 mm Hg pressure. These values should not be regarded as precise boundaries between safe and dangerous concentrations. They represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day, without adverse effect. The values refer to time-weighted average concentrations for a normal workday. (c) 2-ethoxyethanol.

chlorinated hydrocarbon to reduce fire hazard. The alcohols are used for special solvent cleaning operations such as the removal of activited soldering fluxes. Acetone and other solvents which have low flash points are used for special purposes only, such as cleaning the components of precision instruments. Acetone and Benzol constitute a serious fire hazard. Their use and storage require strict observance of safety precautions. Solvents such as methylene chloride and chloroform are frequently used in the spray cleaning of relay contactors before they are sealed by covers. Fumes from these sprays must be thoroughly vented.

Solvent cleaning is usually performed at, or slightly above, room temperature. The components are cleaned by either immersion, spraying, or wiping. Agitation of the component assists in the cleaning process. Ultrasonic cleaners use a solvent and ultrasonic sound to vibrate the part. In this manner, removal of soils from deep recesses or other difficult to reach areas is facilitated by ultrasonic vibration.

Traditionally, solvent cleaning is regarded as a method of pre-cleaning or as one reserved for special applications. However, in the manufacture of electronic components and other assemblies that are comprised of many small parts, the use of solvents as a final cleaner has increased. Most solvent cleaning operations fall within one of the following categories:

- Inexpensive pre-cleaning of components that later will be further cleaned by another method.
- Hand cleaning of components too large for immersion or spray machine cleaning.
- Cleaning of heat sensitive or chemical sensitive components.
- Removal of organic materials such as plating stop-offs, marking crayons or soldering fluxes.

- Cleaning of precision items in a succession of steps in which the component is first cleaned in nonpolar solvent to remove oil and then in water (polar solvent) to remove inorganic solvents.
- Temporary general cleaning where the cost of vapor degreasing equipment is not justified.
- Cleaning of electrical or electronic components in which the presence of inorganic salt deposits may cause current leakage.

Safety precautions for fire and toxicity are necessary when solvents are used. (See Table 30-5-1) Typical precautions are:

- Storage and use of flammable solvents in metal containers, such as safety cans.
- Adequate ventilation to prevent the accumulation of vapors and fumes.
- Prohibited use of solvents close to an open flame or heaters with open coils.
- Protection against exposing the skin to solvents. (Protective gloves and/or ointments should be used to prevent extraction of natural oils from the skin which would cause cracking of the skin)
- Protection from inhalation when toxic solvents are used (The vapors of chlorinated hydrocarbons and alcohols are capable of exerting a potentially anesthetic action when inhaled. As an example, trichloroethylene has relatively slight toxic effect, but maintenance personnel have lost their lives after working for prolonged periods inside tanks containing high concentrations of trichloroethylene vapor, as a result of its strong narcotic effect. Perchlorethylene is comparable in toxicity and also is strongly narcotic.)

Emulsion Cleaning

Emulsion cleaning is a process for removing organic soils from the surface of a metal by the use of common organic solvents dispersed in an aqueous medium with the aid of an emulsifying agent. Dependant upon the solvent used, cleaning is performed at temperatures ranging from room temperature to 180°F,

An emulsion system contains two liquids, mutually insoluble, one of which is "dispersed" and the other is "continuous". The "dispersed phase" (also discontinuous phase) is that liquid which is distributed as globules in the other liquid, known as the "continuous phase" liquid. Emulsifying agents are used to permit use of solvent-water emulsions. There are two general types of emulsifying agents: Those that promote the formation of oil-in-water emulsions (water constitutes the continuous phase), and those which form water-in-oil emulsions (water is the dispersed phase).

Emulsion cleaners are classified into four groups on the basis of stability given by the emulsifying agent. There is some overlapping of definitions.

- Stable, Stable Single Phase, or Permanent Emulsions Cleaners - The emulsion is dispersed throughout the continuous phase. The agitation provided by thermal gradients and the motion of the work being cleaned is sufficient to maintain a uniform dispersion.
- Unstable or Unstable Single Phase Emulsion Cleaners - These have a uniformly dispersed discontinuous phase, but require moderate to considerable agitation to maintain dispersion.
- Diphase, Multiphase, or Floating Layer Emulsion Cleaner - These are highly unstable, and form two layers in the cleaning tank. (Work is immersed through the oil-rich surface layer into the water-

rich lower layer. This permits both phases to come in contact with the surface to be cleaned. When used in a spray system, this type of emulsion cleaner resembles an unstable emulsion as the oil and water phases are mixed in the pumping action.)

- Emulsifiable-Solvent System - This process applies a concentrated solvent to the surface to be cleaned followed by a water spray rinse which emulsifies and removes the solvent and soil.

Emulsion cleaners cover a wide range of solvent and emulsifier compositions. The solvent is generally of petroleum origin and typically is paraffinic*, napthenic, or aromatic.** Solvents have boiling points ranging from 140 to 500°F and flash points ranging from room temperature to above 200°F. The lower-boiling solvents are usually more effective in removing soils. However, fire hazards and evaporation losses increase as boiling and flash points decrease.

Emulsifiers include polyethers and high-molecular-weight sodium or amine soaps of hydrocarbon sulfonates, amine salts of alkyl aryl sulfonates, fatty-acid esters of polyglycerides, glycerols, of polyalcohols. Emulsifiers must have some solubility in the oil phase. When solubility is low, a blending agent such as ester or ether, is added to increase solubility. The blending agent must be soluble in oil and water.

Typical compositions and operating temperatures ranges for emulsion concentrates are illustrated in Table 30-5-2.

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* a hydrocarbon of the methane series

** characterized by the presence of at least one benzene ring - used of hydrocarbons and their derivatives.

Table 30-5-2. Typical Emulsion Concentrations

Component	Composition, parts by volume		
	Stable	Unstable	Diphase
Petroleum solvent (a).....	250 to 300	350 to 400	250 to 300
Soaps (b).....	10 to 15	15 to 25	None
Petroleum (or mahogany) sulfonates (c).....	10 to 15	None	1 to 5
Nonionic surface-active agents (d).....	5 to 10	None	1 to 5
Glycols, glycol ethers (e).....	1 to 5	1 to 5	1 to 5
Aromatics (f).....	5 to 10	25 to 50	5 to 10
Water (g).....	5 to 10	None	None
Typical Operating Temperature Range (h)	80 to 150 F	80 to 150 F	80 to 140

(a) Two commonly used hydrocarbon solvents are deodorized kerosene and mineral seal off. (b) Most commonly used soaps are based on rosin or other short-chain fatty acids, saponified with organic amines or potassium hydroxide. (c) Low-molecular-weight petroleum sulfonates ("mahogany sulfonates") are used for good emulsification plus some rust protection. High-molecular-weight sulfonates offer good rust inhibition and fair emulsification. (d) Increased content generally improves stability in hard water, but increases cost. (e) Glycols and glycol ethers are generally used in amounts necessary to act as "couplers" in the stable and unstable types of emulsions. These agents are frequently used with diphase and detergent cleaners to provide special consolvency of unique or unusual types of soils. (f) Aromatic solvents are frequently used to provide consolvency for special or unique soils; sometimes they serve also to inhibit odor-causing or rancidifying bacteria. (g) Water or fatty acids, or both are used to adjust the clarity and stability of the emulsion concentrate, particularly those of the stable and unstable types. (h) Maximum safe temperature depends on the flash point of the hydrocarbon (petroleum) solvent used as the major component.

Emulsion cleaning is an effective means of removing pigmented drawing lubricants, unpigmented oils, and greases, cutting fluids, polishing and buffing residues, and residues resulting from magnetic particle inspection. Emulsion cleaning is used when rapid superficial cleaning is required and when protection by a light residual film of oil is desirable, or is not objectionable. Emulsion cleaners can be used on virtually any metal as long as the pH of the cleaner is maintained below 10.0. If the cleaner initially has a pH > 10.o or if alkali contamination has brought it above 10.0, the cleaner is not recommended for the cleaning of aluminum or zinc. Emulsion cleaners leave a thin film of oil which provides some protection against rusting.

Emulsion cleaning is not recommended for components that are difficult to thoroughly rinse. Such components are exemplified by sintered powder metallurgy components and components which have blind holes or deep recesses.

Emulsion cleaners have negligible toxicity and irritation to the skin. The fire hazard associated with emulsion cleaners is slight if the temperature of the cleaner is maintained 15 to 20°F below the flash point and adequate ventilation is maintained. Emulsion cleaners containing Stoddard solvent, kerosene, or similar petroleum derivatives, have relatively low flash points and present a potential fire hazard. These cleaners should be kept away from welding, heat treating and similar heat generating operations. Open fire burners of all types must be kept away from emulsion cleaning operations. If it is required to heat the emulsion cleaner, steam is used as the heating medium.

The rate of ventilation required for health and safety reasons is dependent upon the cleaner characteristics, operating temperature, and the efficiency of the baffles on cleaning machines. The removal rate of volatiles varies from as little as 1 to 250 cfm for each square foot of

cleaner surface area. Spray operations require more ventilation than immersion operations because the area of air/liquid interface and the velocity are greater.

Acid Cleaning

Acid cleaning is a process in which a solution of a mineral acid, organic acid or acid salt, in combination with a wetting agent and detergent, is employed to remove oxide, shop soil, oil, grease, and other contaminants from metal surfaces, with or without the application of heat. The distinction between acid cleaning and acid pickling is a matter of degree. Generally, acid pickling refers to a more severe treatment for the removal of scale from semi-finished mill products, forgings or castings. The term acid cleaning is used when the acid solution is employed for final or near final preparation of metal surfaces prior to plating, painting or storage.

Acid cleaners consist of many combinations of mineral and organic acids and solutions of acid salts. These acids may employ the use of surfactants (wetting agents), inhibitors, and solvents. With respect to composition, the many formulations of which acid cleaners are comprised can be classified as (1) Inorganic (mineral) acid solutions, (2) Organic acid solutions, (3) Mixtures of (1) and (2), (4) Acid-solvent mixtures, and (5) Solutions of acid salts.

Compositions and operating conditions of several typical formulations used for cleaning ferrous metals are listed in table 30-5-3.

The phosphoric acid-ethylene glycol monobutyl ether mixtures are widely used for removing grease, oil, drawing compounds, and light rust from iron and steel. These mixtures are adaptable to immersion, spray or wiping methods and leave a phosphate coating which provides a paint base and temporary resistance to rusting. Mixtures containing

chromic acid are often used as final rinses in acid cleaning-phosphating systems. The chromic acid enhances the corrosion resistance of the surface and enables the rinse to clean excess and unattached phosphate from the surface of the metal without leaving hard water salts deposited on the surface.

Table 30-5-3. Acid Cleaner Formulations and Conditions for Cleaning of Ferrous Metals.

	Immersion		Spray		Barrel	Wipe	Electrolytic
Composition, % by Weight							
Phosphoric acid	70	....	70	....	....	15 to 25	....
Sodium acid pyrophosphate	....	16.5	....	16.5	16.5	....	....
Sodium bisulfate	....	80	....	80	80	....	....
Sulfuric acid	....	....	....	....	....	....	55 to 70
Nonionic wetting agent(A)	5	....	5	....	....	7 to 20	....
Anionic wetting agent	(B)	(B)	(B)(C)	(B)(C)	(B)(C)	(B)(D)	(B)
Other Additives	25(B)	....	25(B)	....	....	Rem	Rem
Operating Conditions							
Concentration, oz per gal	16	8 to 16	8	2 to 4	2 to 8	....	....
Current density, amp/sq ft	....	....	....	....	....	....	100
Temperature, F	160	140	140	140	Room	Room	70

(A) Ethylene glycol monobutyl ether is commonly used. (B) Inhibitors up to 1% concentration may be used to minimize attack on metal. (C) An antifoaming agent is usually required when the cleaner is used in a spray or barrel system. (D) Small additions of sodium nitrate are often used as an accelerator in cleaning rolled steel; nickel nitrate is used in cleaning galvanized steel. (E) Before dilution.

To reduce the amount of acid attack on the metal, inhibitors are included in cleaners used on ferrous metals. Both naturally occurring and synthetic inhibitors are used in acid cleaning although naturally occuring inhibitors vary widely in uniformity and effectiveness. For this reason, the use of synthetic inhibitors is increasing. Examples of naturally occuring inhibitors are waste animal materials, off-grade wheat flour, and sulfonation products of such materials as tar, coal tar, and asphaltum. Synthetic inhibitors are exemplified by complex structures of amines, aldehydes, thioaldehydes, mercaptans and other organic compounds. The amount of inhibitor required is dependent upon the workpiece composition, acid cleaner formulation, temperature of operation and the nature of the

soil to be removed. Increasing the solution operating temperature increases the rate of attack in both inhibited and uninhibited acid cleaning solutions.

Antifoaming agents may be required to prevent excessive foaming in acid spray systems. In many cases, foaming can be reduced by the use of hard water and by the addition of small amounts of calcium chloride. Addition of one of the high molecular weight polyols or a plasticizer such as triethylhexylphosphate will reduce foaming. Silicones are usually effective as antifoaming agents although they are not recommended if the components are to be plated or painted. Such an application produces contamination that causes "fisheyes" on the finished component. From plant to plant, it may be necessary to try several different antifoaming agents before foaming is brought under control due to the variations in water and other conditions.

The selection of a method of acid cleaning is dependent upon the nature of the soil to be removed, the size and configuration of the workpiece, the quantity of similar pieces to be cleaned, and the type of acid cleaner used. Methods include wipe on-wipe off, spraying, immersion, rotating barrel, and electrolytic.

- Wipe on-wipe off method - This is the most simple method. A suitably protected operator wipes the soiled workpiece with an acid-impregnated cloth or sponge. After the cleaner is allowed to react, the work is rinsed with water. Reaction times of 2 to 3 minutes is usually sufficient. The wiping method is practical for cleaning a few components at a time or for large, bulky components that can not be immersed conveniently in a cleaning bath.

- Spray cleaning method - This method is more practical for large quantities of bulky components. The types of acid cleaners that are practical for spray cleaning is somewhat limited. Table 30-5-3 illustrates the typical formulations used in spray acid cleaning systems. Strong acids such as sulfuric and hydrochloric are infrequently used for this method. Multistage spray washers have been designed to accomodate a large variety of work that can be racked or suspended from hooks.
- Immersion method - The most versatile of acid cleaning methods is the immersion system. Any type of acid cleaner may be employed. Immersion system operation varies from dipping a single part or agitating a basket containing several parts in an earthenware crock at room temperature, to a sophisticated, automatic agitation system operating at elevated temperatures.
- Barrel (tumbling) method - In this method, perforated barrels containing 500 to 1000 pounds of work is immersed and rotated in tanks containing the acid salts. Barrel acid cleaning is used for large quantities of small parts. A medium such as stone is included in the barrel to improve cleaning by providing an abrading action and to prevent the workpieces from damaging each other.
- Electrolytic method - In electrolytic cleaning, an electric current is passed through the acid bath. Sulfuric acid baths are mostly used. The mechanical scrubbing resulting from the evolution of gas and the chemical reduction of surface oxide films make electrolytic cleaning effective. Phosphoric acid is unsuitable for electrolytic cleaning due to the excessive evolution of gas. To prevent the excessive

contamination of the electrolytic bath, major amounts of grease and oil are removed prior to electrolytic cleaning. When alkaline cleaners are used as pre-cleansers, a thorough rinse is accomplished prior to the electrolytic bath to prevent alkali contamination of the bath. Electrolyzed acid solution time cycles must be short, usually less than two minutes, or excessive etching will occur. Current distribution must also be uniform or localized etching may damage the component.

Any acid cleaning normally etches the item. Although advantageous for many final finishing operations, when etching is not permissible, some other cleaning method must be employed. Limitations of acid cleaning include (1) Inability to remove heavy deposits of oil or grease without the addition of expensive material such as ethylene glycol monobutyl ether, (2) metal attack to some degree even when inhibitors are used, and (3) requirement for acid-resistant equipment.

Acid Pickling

Pickling is the chemical removal of surface oxides from metal by immersion in an acid solution. Pickling is the most efficient method of scale removal for large tonnage products such as merchant bars, blooms, billets, sheet, strip, wire and tubing.

The most commonly employed pickling acid is sulfuric acid. Table 30-5-4 illustrates some typical solution concentrations and operating temperatures employed for pickling carbon and alloy steel products.

For batch pickling of hot rolled or heat treated high-carbon steel rod and wire, hydrochloric acid is preferred. Hydrochloric acid produces a uniform light-gray surface and decreases the possibility of overpickling, which pro-

duces a black smut on the surface. Operating conditions for batch and continuous pickling in hydrochloric acid solutions are illustrated in Table 30-5-5.

Table 30-5-4

Typical Solution Concentration and Operating Temperatures Employed for Pickling Carbon and Alloy Steel Products

Product	Sulfuric acid concentration, % by weight		Bath temperature, F	
	Min	Max	Min	Max
Bars, low-carbon	7	15	155	185
Bars, alloy	9	12	150	170
Billets, low-carbon	7	12	165	180
Billets, alloy	9	12	180	200
Pipe for galvanizing	7	15	160	190
Sheet for galvanizing	4	12	150	170
Sheet, tin plant (white pickle)	9	12	150	185
Strip, soft	6	12	170	190
Strip, alloy and high-carbon	7	12	150	170
Strip, continuous pickling	23	38	170	212
Tubing, low-carbon seamless	7	12	170	190
Tubing, high-carbon and alloy structural	9	12	160	200
Tubing (over 0.40% C)	9	12	140	160
Wire, soft	4	11	170	190
Wire, alloy and high-carbon	3	7	145	165
Fabricated parts (for tinning):				
Initial pickle	5	10	150	190
Final dip	Conc HCl, 18-20° Be'		...	100

Table 30-5-5. Hydrochloric Acid Solution

	Batch	Continuous
HCL, & by Weight	8 to 12	15 to 20
Temperature, F	100 to 105	120 to 140
Immersion Time	5 to 15 minutes	1 to 20 seconds
Maximum Allowable Iron Concentration in Bath, % by Weight	13	5 to 8

As in acid cleaning, natural or synthetic inhibitors are added to the acid pickling solutions. Inhibitors are added primarily to protect the steel being cleaned by retarding or stopping the chemical action of the acid on the base metal. Inhibitors perform five functions in the pickling process: (1) Minimize the loss of iron, (2) Reduce the extent of hydrogen embrittlement*, (3) Protect the metal against pitting, caused by over-pickling and poor surface quality, (4) Reduce acid fumes resulting from excessive reaction between the acid and the base metal, and (5) Reduce acid consumption.

Chelating

Chelating is a process for removing organic and inorganic soils by the use of chelating agents. Cold working operations require the use of drawing lubricants which contain compounds of zinc, magnesium, calcium, or iron. Such lubricants are difficult to remove but can be cleaned with alkaline cleaners containing the proper chelating agents. A chelate is a ring structure that usually contains a metal ion held by coordination bonds. Chelates accelerate clean-

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* Hydrogen embrittlement is a mechanical-environmental failure process that results from the initial presence or absorption of excessive amounts of hydrogen in metals, usually in combination with residual or applied tensile stresses. In some types of hydrogen embrittlement, cracking is promoted by high internal pressure caused by the combination of atomic hydrogen into molecular hydrogen gas at internal discontinuities or inclusions of the metal. It has been suggested that hydrogen enhances cracking because hydrogen absorption at these sites lowers the surface energy required for cracks to grow. Another suggestion is that hydrogen reduces the bonding energy of the metal lattice sufficiently to allow cracking.

ing by reacting with the metal ion in the lubricant to form a metal chelate and an acid. As an example, a calcium stearate type of lubricant is only slightly soluble in an alkaline solution. However, when the proper chelating agent is present in the solution, the calcium ions which go into solution combine with the chelate to form metal chelate molecules. As the calcium ions combine with the chelate, more calcium stearate dissolves and the cleaning process rapidly progresses to completion.

Sodium salts are combined with the chelating agents to form a dry, concentrated powder. The cleaning solution is produced by dissolving the powder in water. The chelates commonly used in alkaline cleaning solutions are citric acid, ethylenediamine tetraacetic acid (EDTA), gluconic acid, and nitrilatriacetic acid.

Vapor Degreasing

Vapor degreasing is a term applied to the cleaning process which employs the hot vapors of a chlorinated solvent to remove soils. Vapor degreasing is effective in the removal of oils, greases, and waxes.

Vapor degreasing is accomplished by the use of a vapor degreasing unit. The unit consists of an open steel tank with a heated solvent reservoir (sump) at the bottom. A cooling zone is located near the top of the tank. Heat is introduced into the sump to boil the solvent and generate hot solvent vapor. As the hot vapor is heavier than air, it displaces the air and fills the tank up to the cooling zone. As it reaches the cooling zone, the hot vapor is condensed thereby maintaining vapor level and creating a thermal balance. The temperature differential between the hot vapor and the cool workpiece causes the vapor to condense on the workpiece and dissolve the soil. As a supplement to vapor cleaning, some degreasing units are equipped

with facilities for immersing the work in warm or boiling solvent and for spraying the workpiece surfaces with clean solvent. The efficiency of the liquid phase of the cleaning cycle can be increased with the use of ultrasonic vibration. Figure 30-5-1 illustrates the principle systems of vapor degreasing.

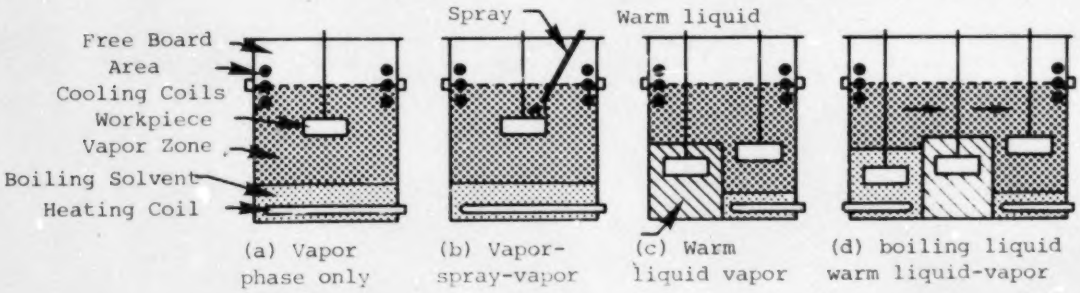


Figure 30-5-1. Principal Systems of Vapor Degreasing

The degreasing system of simplest form is the Vapor Phase Only system. The workpiece is lowered into the vapor zone. The relative coolness of the workpiece causes the vapor to condense on the workpiece. The soil is dissolved and removed from the workpiece by the condensate dripping back into the boiling solvent. As the workpiece approaches the temperature of the hot vapor, condensation and cleaning action cease.

When a workpiece contains blind holes or recesses which are not accessible to the vapor, the Vapor-Spray-Vapor method of vapor degreasing is employed. Preliminary cleaning is accomplished by the vapor phase. When condensation ceases, the workpiece remains in the vapor zone and is sprayed with warm solvent. The pressured spray forces liquid solvent into the blind holes and removes stubborn soils that can not be removed by vapor alone. The temperature of the workpiece is also lowered by the liquid spray, allowing further condensation of vapor for a final rinse.

Temperature equalization may occur prior to completion of workpiece cleaning on workpieces which are comprised of small parts with thin sections. The Warm Liquid-Vapor System of vapor degreasing is recommended in this case. The workpiece is held in the vapor zone until condensation ceases. The workpiece is then lowered into warm liquid solvent where agitation mechanically removes some of the soil and the temperature of the workpiece is lowered. From the warm liquid, the workpiece is transferred to the vapor zone for a final rinse.

The fourth method of vapor degreasing is the Boiling Liquid-Warm Liquid-Vapor System. This method provides satisfactory cleaning of small workpieces which are nested or packed closely together in baskets and for workpieces which have particularly heavy or adherent soil. In this system, the workpiece may be held in the vapor zone until condensation ceases and lowered into the boiling liquid, or the workpiece may be lowered directly into the boiling liquid. The boiling liquid scrubs off most of the heavy deposit as well as metal chips and insolubles. The work is transferred to the warm liquid which removes dirty solvent and lowers the workpiece temperature. The workpiece is finally transferred to the vapor zone where condensation provides a final rinse.

Ultrasonic degreasing can be used in conjunction with vapor degreasing. Cleaning efficiency of the liquid phase of vapor degreasing is significantly increased by the application of ultrasonic energy. Ultrasonic degreasing is often applied to components that are too small or intricate to receive maximum benefit from conventional degreasing cycles. Examples of components cleaned by ultrasonics because they failed to respond to conventional degreasing methods are: small ball bearing and shaft assemblies, printed circuit boards (removal of soldering flux), intricate

relays, plug-type valve inserts (contaminated with lapping compounds), and strands of cable (removal of soil and other manufacturing contaminants trapped between the strands).

Vapor degreasing system use chlorinated hydrocarbons which are toxic when inhaled. Chlorinated hydrocarbons affect the mucous membranes and the linings because they extract oil from the skin which may cause cracking and dermatitis. Prolonged or repeated exposure of the skin to these solvents should be avoided. Properties of vapor degreasing solvents are listed in Table 30-5-6.

Table 30-5-6. Properties of Vapor Degreasing Solvents

Property	Trichlor-ethylene	Perchlor-ethylene	Methylene chloride	Trichloro-trifluoro-ethane	Methyl chloroform (1,1,1-tri-chloroethane)
Boiling point, F.....	188	250	104	118	165
Flammability.....	Nonflammable under vapor degreasing conditions				
Kauri-butanol value.....	130	90	135	30	130
Latent heat of vaporization (a).	101	90	142	61	95
Saturation in air (b).....	0.03	0.008	0.19	0.27	0.06
Specific heat (c).....	0.23	0.21	0.28	0.21	0.26
Specific gravity:					
Vapor (air = 1.00).....	4.54	5.73	2.93	6.75	4.50
Liquid (water = 1.00).....	1.464	1.623	1.326	1.514	1.327
Threshold limit, ppm (d).....	100	100	500	1000	500

(a) At boiling point, in Btu per pound. (b) 100% relative humidity at 68°F, in pounds of solvent per cubic foot of air. (c) Of liquid, in Btu per pound per °F. (d) Parts of vapor or gas per million parts of air by volume at 25 C and 760 mm Hg pressure; values adopted at 1962 meeting of American Conference of Governmental Industrial Hygienists. These values should not be regarded as precise boundaries between safe and dangerous concentrations. They represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect. The values refer to time-weighted average concentrations for a normal workday.

Abrasive Blast Cleaning

Abrasive blast cleaning is the forceful direction of abrasive particles (either dry or suspended in a liquid) against the surfaces of metal components to remove contaminants or to condition the surfaces for subsequent finishing. Abrasive blast cleaning is used to (1) remove rust, scale, dry soils, weld sand or paint, (2) roughen the surfaces in preparation for bonding, painting, or other coating, (3) remove burrs, and (4) develop a matte surface finish.

The materials used in dry abrasive blast cleaning may be categorized as grit, shot, "sand", and miscellaneous. Grit consists of angular metallic particles (usually, crushed hardened cast steel, which may be tempered, or chilled white cast iron, with high cutting power. Shot is normally made of the same materials as grit and is usually in the form of spherical particles; it removes scale, sand and other surface contaminants by impact. Shot also may be made of aluminum or cut steel wire. Cut steel wire deforms into rounded particles during usage. "Sand" is a term applied to a wide diversity of nonmetallic abrasives in addition to ordinary silica sand. These materials are used when it is necessary to protect the surface of the workpiece from metallic contamination. they may be either natural materials (such as garnet, novaculite, dolomite, pumice and flint quartz) or manufactured materials (such as aluminum oxide, silicon carbide and slag). Miscellaneous Materials give a mild abrasive action and include such agricultural products as crushed walnut or pecan shells, rice hulls, rye husks, corncobs and sawdust. Smooth glass or plastic beads service a similar purpose. Table 30-4-7 lists typical abrasives for various applications. Regardless of the materials used for dry blasting, the following generalizations apply.

- As abrasive particle size decreases, the surface finish is finer and surface coverage is greater.
- As abrasive particle increases in size, the impact is greater resulting in more upsetting of metal (pruning or cutting).
- As abrasive particle hardness increases, cleaning action is faster.

Table 30-5-7

Typical Abrasives, Equipment and Cycles Employed for Dry Blasting

Material or product	Reason for blasting	Abrasive		Equipment		
		Type	Size No.	Type	Horsepower or nozzle diameter	Blasting cycle
Ferrous Metals						
Cast iron	Prepare for zinc impregnation	Iron grit	G80	Air, table(a)	¼ in.	1 hr
	Remove molding sand	Steel shot	S230	Wheel, barrel	15 hp	10 min
Cold rolled steel	Remove graphite for painting	Iron grit	G80	Wheel, barrel	15 hp	10 min
				Air, table(a)	¼ in.	40 min
Gray iron exhaust manifolds, bearing caps	Clean for machining	Malleable iron shot	S460	Wheel, tumble(b)	80 hp	1500 pieces per hr
Gray iron motor blocks and heads	Remove sand and scale after heat treatment	Malleable iron shot	S550	Wheel, blast cabinet(c)	150 hp	0.19 to 0.27 min per piece
Hardened steel screws	Remove heat treat scale	Iron grit	G80	Wheel, barrel	10 hp	5 min
Hot rolled steel	Prepare for painting	Iron grit	G80	Air, table(a)	¼ in.	1 hr
Malleable iron castings	Prepare for galvanizing	Steel grit	G50	Wheel, barrel	40 hp	15 min
Pole-line hardware	Prepare for galvanizing	Steel grit	G50	Wheel, barrel	40 hp	15 to 20 min
Round steel bar	Etch for adhesive coating	Iron grit	G80	Air, blast room	¼ in.	2 min
Soil-pipe fittings	Remove molding sand	Steel shot	S330	Wheel, barrel	30 hp	400 lb in 5 min
Steel drums	Prepare for painting	Iron grit	G80	Air, blast room	¼ in.	4 min
Steel rod	Clean for wiredrawing	Steel grit	G40	Wheel, continuous(d)	80 hp	40 to 300 fpm
Steel screws	Prepare for plating	Iron grit	G80	Air, barrel(a)	5/16 in.	20 min
Structural steel	Prepare for painting	Steel grit	G40	Wheel, continuous(d)	80 hp	30 fpm
Weldments (steel)	Remove scale, welding flux and spatter, for painting	Steel grit	G25	Wheel, barrel	30 hp	300 to 600 lb in 7 min
Nonferrous Metals						
Aluminum	Produce frosted surface	Sand	50	Air, barrel	¼ in.	20 min
	Prepare for painting	Iron grit	G80	Wheel, barrel	15 hp	5 min
Bronze	Produce frosted surface	Sand	50	Air, barrel	¼ in.	20 min
Nonmetallic Materials						
Clear plastic parts	Produce frosted surface	Sand	50	Air, barrel	¼ in.	15 min
Hard rubber	Improve appearance	Sand	50	Air, barrel	¼ in.	20 min
Molded plastic parts	Remove flash	Walnut shells	...	Wheel, barrel	10 hp	8 min
Phenolic fiber	Produce frosted surface	Sand	50	Air, barrel	¼ in.	30 min
	Prepare for painting	Sand	50	Air, barrel	¼ in.	20 min

(a) Four air nozzles. (b) Two wheels, 40 hp each. (c) Six wheels, 25 hp each. (d) Four wheels, 20 hp each.

The two basic methods of dry blast cleaning are mechanical and air blasting. Mechanical blasting consists of the abrasive being propelled by means of a power-driven, rapidly rotating, bladed wheel. Air blasting consists of the abrasive being propelled through a nozzle by compressed air.

The abrasive particles employed in wet blast cleaning are usually finer than those in dry blast cleaning. The abrasive particles are suspended in chemically treated water to form a slurry. The slurry is continuously agitated to prevent settling and is forced by compressed air through nozzles which are directed at the workpiece.

Wet blasting is not intended for the removal of heavy scale, coarse burrs or heavy soil. The wet blasting method of abrasive cleaning is intended to produce only relatively slight effects on the workpiece surface. Wet blasting is commonly used for:

- removing small burrs on precision parts
- production of satin or matte finishes
- inspecting finish ground hardened parts
- removing fine tool marks from hard parts
- removal of light mill scale or machining marks preparatory to plating
- removal of surface oxide preparatory to soldering of electronic components and painted circuits
- removal of welding scale

In the majority of instances, precleaning is accomplished prior to wet blasting to prevent contamination of the slurry. Protective coatings, grease and heavy oil are removed by conventional degreasing methods prior to wet blasting. A light layer of rust may be removed by wet blasting without precleaning. Generally, however, the finer the abrasive used in the wet blast slurry, the greater is the need for precleaning to preclude slurry contamination.

Numerous kinds and sizes of abrasives are used in wet

blasting. Table 30-5-8 lists the characteristics and typical applications of abrasives used in wet blasting.

Table 30-5-8

Characteristics and Typical Applications

of Abrasives Used in Wet Blasting

Abrasive	Size, mesh	Characteristics and applications
Silica	40 to 80	Fast-cutting. Used for deburring steel and cast iron, removing oxides from steel. Close tolerances cannot be held.
Silica	80	Fast-cutting. Used for deburring steel and cast iron, roughening surfaces for plastic bonding or rough plating. Has peening action. Tolerances cannot be held.
Quartz (ground)	80	Very fast-cutting. Used for removing heavy burrs, light or medium scale, excessive rust. Can be used on nickel alloy steels. Tolerances cannot be held.
Novaculite	100	Fast-cutting. Used for cleaning carbon from piston and valve heads; deburring brass, bronze and copper. Can be used on crankshafts. Tolerances cannot be held.
Quartz (ground)	100, 140	Fast-cutting. Used for blending-in preliminary grind lines on steel, brass and die castings; removing medium-hard carbon deposits; blasting radii of 0.005 to 0.010 in.
Silica	140	Used for removing small burrs from steel, copper, aluminum and die castings; rough cleaning of dies and tools; removing metal. Tolerances cannot be held.
Novaculite	325	Slow-cutting. Used in first stage for cleaning master rods and glass, and in second stage for cleaning aluminum pistons, crankshafts, impellers, valves. Holds tolerances to 0.0025 in.
Aluminum oxide	400	Fast-cutting. Used on stainless steel and on zinc and aluminum die castings. Excellent for oil-contaminated surfaces.
Novaculite	1250	Used in second stage for cleaning crankshafts, impellers, rods, pistons, valves, gears and bearings. Also for polishing metals, tools, dies and die castings. Tolerances can be held.
Novaculite	5000	Used for obtaining extra-fine surfaces on parts.
Bright shot (glass beads)	20 to 400	Used for removing light scale or discoloration after heat treating, removing light oxide from jet-engine and electronic components. Produces peening effect.

The health hazard associated with blast cleaning is silicosis. Silicosis is a disease of the lungs that results from the prolonged breathing of very fine particles of silica. The effects of silicosis can be permanently disabling and even fatal. A common practice is to have the blaster personnel x-rayed prior to employment and at least once a year thereafter. The films should be read by a physician specializing in this particular field.

Sand blasting of sand-free steel or iron castings and shot blasting of sandy castings produce enough fine silica to make the air dangerous to breathe. Blaster personnel are protected by a helmet supplied with air, special gauntlets, an apron, and special spats. The air supplied to blaster personnel is approximately 6 cubic feet per minute,

clear, odorless, dry, and free from gaseous contaminants.

Salt Bath Descaling

Salt bath descaling processes are affective in removing tight-adhering scale from nickel-base alloys, cobalt-base alloys, and some grades of stainless steel. The process is classified as reducing, oxidizing, or electrolytic.

The reducing process of salt bath descaling consists of immersing the workpiece in a molten sodium hydroxide bath containing 1.5 to 2.0% sodium hydride. Sodium hydride descaling involves the chemical reduction of metal oxides to the metallic state or to lower oxides. The reduced material is then readily removed from the work by a water quench followed, when required, by appropriate acid dips.

Workpieces are immersed and held in the bath until the reducing action on the scale has ceased. Treatment duration is dependent upon the type of base metal and the type and amount of scale. Duration may range from a few seconds to 20 minutes. Upon completion of the reducing cycle, the workpiece is removed from the bath, allowed to drain for a short period, and quenched in water. Varying amounts of reduced scale are "blasted" from the surface, exposing base metal, during the quenching phase. Subsequent to quenching, the workpiece is immersed in acid solutions, followed by water rinsing, producing a bright, clean metal surface.

In the oxidizing process, sodium hydroxide, in conjunction with various other oxidizing salts, performs an active function in the carrier bath, unlike its function in the reducing process. Varying according to different proprietory formulations, the ratio of salts and types of oxidizing agents is typically represented by (1) 60% to 90% sodium hydroxide, (2) 7% to 32% sodium nitrate, and (3) 1.5% to 6% sodium chloride. The preferred operating temperature is approximately 900°F although the temperature may range from

800 to 1000°F.

Scale consists of both lower and higher oxides. When a scaled workpiece is immersed in an oxidizing salt bath, both the metal and the scale are heated to operating temperature. However, the unequal expansion rates of the metal and scale result in the cracking of the scale. The salt penetrates the cracks and oxidizes the lower oxides to form soluble salts and water. This reaction disrupts the physical dimension of the scale and causes the scale to become soft and porous.

A violent activity occurs when the workpiece is quenched. Steam causes the scale cracks to open further. A portion of the scale is rinsed away while the remainder is loosened and conditioned for rapid removal by pickling or acid dipping.

An electrolytic salt bath is designed principally for continuous operation although it may be used as a batch-type process. In the continuous operation for cleaning strips, two tanks, each insulated from the other, contain baths of similar concentrations of sodium hydroxide, sodium chloride plus sodium fluoride, and sodium carbonate. The bath temperatures are maintained at 900°F. Continuously, the strip is passed from a gas-fired annealing furnace through the two electrolytic descaling tanks. A direct current passes from cathodic grids to the strip in the first tank. In the second tank, the current passes from the strip to anodic grids. The strip is passed on to pickling, scrubbing and drying equipment from the second tank. The salt action is neutral until current is applied. The salt oxidizes the scale as the strip becomes positive in the first tank. As the strip becomes negative in the second tank, the salt and the evolution of hydrogen gas remove the higher oxides from the strip.

Compared with acid pickling or mechanical descaling methods, salt bath descaling offers several advantages although it also has disadvantages. Its advantages include (1) Extended range of alloys that can be effectively descaled, (2) more efficient removal of scale from surface discontinuities, (3) Shorter time for descaling of all grades of stainless steel, (4) more uniform surface finish by eliminating the pitting and localized etching that result from the selective action of pickling acid at scale breaks, (5) virtual elimination of metal loss (which can amount to 1 to 3% in acid pickling), (6) elimination of hydrogen embrittlement of steel, and minimization of embrittlement caused by acid pickling, through reduction of acid treating requirements, and (7) less destructive than mechanical descaling to smooth finishes. Its disadvantages include (1) high operating temperatures, (2) distortion of relatively thin-gage materials (0.032 in. and less), (3) increased maintenance cost, (4) electrolytic pitting and possible ignition of titanium and its alloys, and (5) ineffective in removing heavier scale (such as that on hot rolled, box annealed strip) in the time afforded by continuous strip processing.

For any operation involving fused salts at 700-1000^{o}F, safety precautions must be observed during the use and servicing of salt bath descaling equipment. Extreme care must be taken to prevent water from coming in contact with the bath and with metallic sodium. A violent reaction takes place and molten caustic will splatter when contacted by water. Workpieces must be thoroughly dry prior to immersion in a salt descaling bath. Magnesium and magnesium alloys must not be used in salt descaling baths as they will burn. Workpieces entering the bath must also be free of cyanide or a violent reaction will occur.

Alkaline Cleaning

Oily, semisolid and solid soils are removed by alkaline cleaning methods. Alkaline cleaning is employed to prepare metallic surfaces for electroplating, conversion coating, or otherwise finished or processed. The solutions used in alkaline cleaning depend upon their detersive properties for cleaning action and effectiveness. An alkaline is a solution which has a pH greater than 7.

The effectiveness of alkaline cleaners is attributed mainly to the action of "builders", the bulk components of alkaline formulations. The common builders employed are carbonates, phosphates, silicates and hydroxide.

Carbonates serve as buffers, as sources of alkalinity, and as water softeners. The carbonates are poor cleaners, but they supply a fair amount of alkalinity (a 1% aqueous solution, for example, gives a pH of 11.5). However, the real value of carbonates is in helping to keep compounded cleaners dry and free-flowing. This is especially important for cleaners containing a large amount of sodium hydroxide.

Phosphates, such as trisodium phosphate, tetrasodium pyrophosphate and sodium tripolyphosphate also have some* sequestering properties.

Silicates make up the largest portion of most heavy-duty alkaline soak cleaners. Sodium orthosilicate, sodium metasilicate, and sodium sesquisilicate are excellent emulsifiers, are good buffers at pH above 9, hold soils in suspension, and provide active alkalinity.

* Sequestrant - A material that combines with metal ions to form water-soluble complex compounds.

Sodium hydroxide (caustic soda) is inexpensive and is often the principal builder for supplying the necessary alkalinity. In addition, it increases electrical conductivity of the solution and improves saponification. However, its detergent ability is very poor for the nonsaponifiable soils, and it has the poorest rinsing properties of all the common builders.

Surface-acting (wetting) agents are added to alkaline cleaning solutions to lower surface and interfacial tensions and, therefore, to enhance the cleaning action of the cleaner. The surface-acting agents are composed of soaps and synthetic detergents, commonly called syndets.

Sodium resinate, a by-product of the kraft papermaking process, is an extensively used soap. Several grades of sodium resinate are commercially available. Higher grades are more costly, as a result of their refining, but produce only slightly better cleaning than the middle grades. The low grades contain a fairly high content of unsaponified fatty acids, which form insoluble calcium, magnesium and iron soaps with hard water. They should be used with a water-softening agent. In small amounts, resinate soaps do not lower surface and interfacial tensions as much as synthetic detergent. However, resinates emulsify certain soils more easily than do the syndets, thereby justifying their use in alkaline cleaners. Most soak cleaners contain both resinates and syndets.

Synthetic detergents are extensively used as surface-active agents because they are freer-rinsing than soaps, aid soil dispersion, and prevent resoiling. They are effective in softening hard water and in lowering surface and interfacial tensions. In addition, the syndets are less susceptible than soaps to contamination by acid residues. Two types of syndets, anionics and nonionics, are commonly used. The usual concentration range is

0.01% to 1.0% active. The anionics generally are the least expensive of the syndets, and when in solution produce abundant suds. Alkyl aryl sodium sulfonate is the most extensively used anionic. The nonionics usually produce less suds than the anionics. The nonionics most commonly used are sulfonated esters and ethers, and those of the polyoxyethylene type. The latter is a combination of ethy lene oxide condensed on a base such as polyoxypropylene. Lower percentages of ethylene oxide make the substance hydrophobic, increasing its solubility in oil; higher percentages increase its solubility in water (make it hydrophilic) and also increase its foaming properties. Table 30-5-9 lists the typical alkaline cleaner formulations employed for cleaning various metals

Table 30-5-9

Typical Alkaline Cleaner Formulations for Various Metals

	Aluminum		Copper			Cu plate	Iron and steel			Magnesium		Zinc		
	Soak	Spray	Soak	Spray	Electro-lytic	Electro-lytic	Soak	Spray	Electro-lytic	Soak	Spray	Soak	Spray	Electro-lytic
Composition of Cleaner, % by Weight														
Builders:														
Sodium hydroxide, ground	...	...	20	15	15	55	20	20	55	20	20	...	15	15
Sodium carbonate, dense	...	...	15	...	...	8	15	25	8.5	15	25	...	...	...
Sodium bicarbonate	21	24	...	34	34	...	...	...	...	...	...	...	35	34
Sodium tripolyphosphate	30	30	...	...	10	...	20	20	10	20	20	90	10	10
Tetrasodium pyrophosphate	...	...	20	10	...	10	...	...	...	...	...	...	...	...
Sodium metasilicate anhydrous	45	45	30	40	40	25	30	30	25	30	30	...	40	40
Surface-active (wetting) agents:														
Sodium resinate	...	...	5	...	...	...	5	...	...	5	...	5	...	...
Alkyl aryl sodium sulfonate	3	...	5	...	...	...	5	...	1	5	...	5	...	...
Alkyl aryl polyether alcohol	...	...	2	...	...	1	2	...	...	2	...	...	...	...
Nonionics high in ethylene oxide	1	1	...	1	1	1	...	1	0.5	...	1	...	...	1
Other Conditions														
Operating temperature of solution, F	160	160	180	170	160	180	200	170	180	200	170	180	170	180
Concentration of cleaner, oz/gal H_2O	4	1	8	1	8	8	8	1	8	8	1	4	1	8
Relative cost of chemicals(a)	136	121	148	102	104	118	150	107	111	150	107	194	100	104

(a) The cost index is based on the lowest-cost formulation (spray zinc) as 100. The base value of 100 corresponds to a cost of $4 to $8 per 100 lb of the cleaner formulation depending on quantity and local purchasing conditions

Periodic tests must be made on alkaline solutions to control solution strength. Acid soils, hard water, sludge resulting from ion absorption and dilution resulting from water additions weaken alkaline cleaners. Solution strength is determined by the titration method of chemical analysis.

In this method, a control test is made by titrating 0.1 N (N = Normal) hydrochloric acid in a 25 milliliter sample of the solution to a phenolphthalen end point. A duplicate test is performed on a fresh solution of cleaner of the desired point. Comparison of the result indicates the amount of replenishment required to bring the process solution to desired strength.

The double titration method of alkaline solution strength determination is dependent on a chemical titration for equivalent hydroxide and equivalent carbonate. Neutralization is accomplished with a known concentration of hydrochloric acid. The hydroxide is neutralized, and the carbonate is converted to bicarbonate, at an approximate pH of 8.5 (phenolphthalein). Methyl orange is added, and the titration is continued until the bicarbonate is neutralized (pH - 3.8).

The values for the acid concentration, expressed as normality (n), and milliliters of acid used to titrate to each end point are required to determine the concentration of hydroxide and carbonate. If the first end point is A and the second B, both expressed in milliliters, then for this acid-base reaction, N acid X milliliters acid = N base X milliliters base. The only unknown is N base. The volume of acid solution used to neutralize the hydroxide is A-(B-A). The volume of acid used to neutralize the carbonate is 2(B-A).

For a 1N solution of sodium hydroxide, there is 40 g per liter of solution, or 5.35 oz per gal. For a 1N solution of sodium carbonate, there is 53 g per liter, or 7.06 oz per gal. For a 10-ml sample of cleaner, the concentration of the two is derived from these formulas:

Oz per gal Na_2CO_3 =

$$\frac{2(B-A) \times N \text{ acid} \times 7.06}{10}$$

Oz per gal NaOH =

$$\frac{[A-(B-A)] \times N \text{ acid} \times 5.35}{10}$$

Total oz per gal =

Oz per gal Na_2CO_3 + Oz per gal NaOH

Figure 30-5-2. Titration Calculation

A double end point will exist for cleaner solutions made up of other alkalis or containing other alkaline materials. However, the titration does not sort out the constituents. To test for other alkalis, make a liter of solution of the desired strength. As above, titrate a 10 milliliter sample. Calculate the result as though the sodium carbonate and hydroxide were actually present. The calculated ounces per gallon of total cleaner will not be the same as the actual concentration of as-made cleaner, except in the case of sodium carbonate and sodium hydroxide. To find a factor to be used in further titrations of the cleaner in production, divide the as-made concentration by the total as-calculated concentration.

$$f = \text{FACTOR} = \frac{\text{As-Made Concentration (X)}}{\text{As-Calculated Concentration (Y)}} \qquad \text{Formula 30-5-1}$$

For operation, therefore, f times Y equals the cleaner concentration in the production tank.

The difference, in ounces per gallon, between the hydroxide and the carbonate, along with the total amount of cleaner is important for control of the alkaline cleaning process. More equivalent hydroxide is indicated by a large positive difference. This solution composition is normally a harsher cleaner on nonferrous alloys.

In spray washers, the solution balance can be upset due to carbon dioxide reacting with sodium hydroxide and other alkaline materials. At a lower pH, other cleaner materials will hydrolyze or transpose. Additions of sodium hydroxide may counteract the change in cleaner balance.

Experience must be gained in correlating the results of analysis with those of the cleaning process. The double-titration method provides a means of controlling solution strength and reducing consumption of the cleaner. When the cleaner is performing unsatisfactorily, yet the phenolphthalein indicator shows the solution to be in proper specification range, a more complete analysis must be made and/or the solution must be replaced.

The principal methods employed in alkaline cleaning are soak, spray, and electrolytic. The efficiency of soak cleaning, as compared to spray and electrolytic, is limited unless the soil is easily removable. Soak cleaning is generally employed for moderate or small volumes of work. Table 30-5-10 illustrates the basic cycles employed in soak, spray, and electrolytic alkaline cleaning.

The spray method of alkaline cleaning is more effective for removing tenacious soils than the soak method. The advantages of the detersive properties of the solution and the impinging action of the spray are combined in spray cleaning. Spray cleaners have lower detersive properties than soak cleaners because of foaming problems.

The most efficient method of alkaline cleaning is the electrolytic method. The strong agitation of the bath by

gas evolution and the oxidation-reduction reactions during electrolysis combine to establish the effectiveness of this cleaning method. Another important factor in electrolytic cleaning is that similar electrical charges are imparted to certain dirt particles and to the workpiece causing the dirt to be repelled from the work surface.

Table 30-5-10

Basic Alkaline Cleaning Cycles

Variable	Cleaning method		
	Soak	Spray	Electro-lytic
Cleaning			
Time, minutes	3 - 5	½ - 1	½ - 1
Temperature, F	160 - 212	130 - 170	160 - 210(b)
Conc, oz/gal	4 - 8(c)	½ - 1½	4 - 8(c)
Unheated Rinsing			
Time, minutes	¼ - ½	To ¼	½ - ½
Temperature, F	Ambient	Ambient	Ambient
Hot Rinsing			
Time, minutes	½ - 2	To ¼	½ - 2
Temperature, F	160 - 220	130 - 160	160 - 200
Hot-Air Drying			
Time, minutes	1 - 3	½ - 1	1 - 3
Temperature, F	160 - 220	160 - 220	160 - 220

(a) Usually preceeded by soak or spray cleaning. (b) Electrocleaners are seldom operated below 180 F. (c) This may be increased to as much as 12 oz/gal for some severe applications with soak and electrolytic cleaners.

CLEANNESS CONTROL ACTIVITIES

Introduction

Cleanness control activities are planned and outlined by the owner or by direction of the owner to define cleaning and inspection operations to be used during construction and operations phases of nuclear power plants. The principal objective of these activities is to maintain cleanness of supplied items during installation activities of the construction phase and during maintenance and modification activities of the operations phase. One or more of the cleaning methods described by Part I of this module is used only as necessary and whenever unacceptable soils are introduced.

In order to meet the principal objective, cleanness control activities include cleanness classification, pre-installation cleanness installation cleaning, maintenance of installation cleanness, preoperational cleaning, layup, and housekeeping.

Cleanness Classification

The degree of required cleanness is a function of the particular system under consideration. The owner of the nuclear power plant is responsible for establishing the cleanness classification of each system. These classifications consider the susceptibility to corrosion, the consequences of malfunction or failure, and the probability of contaminants contributing to or causing such malfunction or failure. Cleanness classifications are specified on design drawings and associated specifications. Procurement documents specify internal component cleanness requirements consistent with the requirements of the system for which the component is intended. American National Standard, ANSI N45.2.1, describes four cleanness classifications,

all components of the system must meet the acceptance criteria associated with the level of classification.

- Class A Cleanness - The highest cleanness classification level is Class A. Class A is a very high level of cleanness in which there is no evidence of contamination of a component surface. The method of evaluation of Class A cleanness is visual, with or without magnification, or with the aide of sensitive detection methods. Class A cleanness applies to special items such as fuel elements, control rod drive mechanisms, and delicate instruments. Class A components receive their required level of cleanness at the point of manufacture and cleanness is maintained at the construction site.
- Class B Cleanness - Class B cleanness is a high level of cleanness applicable to reactor coolant systems, components and other items such as the reactor coolant purification system. Piping and components in systems which require Class B cleanness must meet the following requirements:
- The surface must appear "metal clean" when examined without magnification under a lighting level (background plus supplementary lighting) of at least 100 foot candles. Scattered areas of rust are permissible provided the aggregate area of rust does not exceed 2 square inches in any one square foot area. (Localized rusting may indicate pitting of the surface and is evaluated metallurgically . Thin temper films resulting from welding or post-weld heat treatments are acceptable.)
- The surface must be free of particulate contaminants such as sand, metal chips, weld slag, etc.
- The surface must be free of organic films and contaminants such as oils, paint, and preservatives as

determined by a visual examination or an organic solvent-dampened white cloth or an equivalent alternate method.

- When a visual inspection is not possible and the surfaces are accessible, a dry white-cloth wipe, followed by a solvent-dampened white-cloth wipe, may be used to evaluate the cleanness of the surface. If either cloth exhibits indications of contamination, the system is recleaned or the specific contaminant is determined and evaluated as to its potential deleterious effect.
- If flushing is the only practical means for determining system cleanliness, the system is evaluated by examining a 20-mesh (ASTM E11-70, Specifications for Wire Cloth Sieves for Testing Purposes) or finer filter, or the equivalent, installed on the outlet of the cleaning circuit. The system is flushed at its normal design velocity (or other velocity if specified by procurement documents) until the screen shows no more than slight particle speckling and no more than slight rust staining. There must not be particles larger than 1/32 inch thickness in any dimension, except fine hairline slivers of less than 1/32 inch thickness are permissible up to 1/16 long. There must not be evidence of organic contamination in the effluent water or on the filter.
- Class C Cleanness - Class C cleanness is an intermediate level of cleanness generally applicable to closed service-water systems that cool components containing reactor coolant, engineered safety systems, and other high integrity systems. Class C Cleanness requires the surfaces to meet the requirements established under Class B cleanness with the

exception of the following:

- Thin uniform rust films are acceptable on carbon steel surfaces.
- Scattered areas of rust are permissible provided that the area of rust does not exceed 15 square inches in any 1 square foot on corrosion resistant alloys.
- Flush-test filters may exhibit considerable rust staining.
- Class D Cleanness - The least stringent cleanness requirements are those established for Class D cleanness. Class D cleanness is applicable to fire-protection, open service water, and similar systems requiring only a nominal degree of cleanness. The following are acceptable on items which meet Class D cleanness:
- Tightly adherent mill scale on carbon steel surfaces.
- Paint or preservative coating on carbon steel surfaces that will not peel or flake when exposed to cold-water flushing.
- Rust films on carbon steel and stainless steel surfaces that resist removal by scrubbing with a bristle brush.
- If flushing is the only practical means of determining system cleanness, the system must be evaluated by examining a 14-mesh or finer filter, or the equivalent, installed on the outlet of the cleaning circuit. The system must be flushed at its normal velocity until the screen shows no more than occasional particle speckling. There must not be particles larger than 1/16 inch in any dimension, except hairlike slivers of less than 1/16 inch thickness are permissible up to 1/8 inch long. There must not be evidence of organic contamination on the screen; considerable rust-staining is acceptable.

Preinstallation Cleanness

Prior to initial installation of components and prior to replacement of components or use of repair parts, the cleanness of the item is determined by inspection. Acceptance criteria is that for the cleanness classification of the system for which the item is intended. Failure to meet the applicable acceptance criteria results in cleaning the item with a method suitable for the soils involved. In this manner, construction, maintenance, or modification activities start with an acceptably clean component or part. The following steps are typically taken by the owner to ensure availability of clean components:

- procurement documents specify the cleanness classification to be met by the component at time of shipment to the plant site by the component supplier.
- procurement documents specify the level of packing and packaging of components in transient to protect the item from physical damage and to maintain its cleanness.
- delivery to the construction site is delayed, where possible, until shortly before the item is to be installed.
- receipt inspection is performed to verify compliance with cleanness classification.
- on-site storage facilities are equipped to maintain cleanness of the item.
- the item is inspected for cleanness at time of use.

With the above controls in place, cleaning of received components is normally unnecessary except for one special condition, i.e., temporary preservatives. Some components, such as carbon steel fasteners, are sometimes protected from atmospheric corrosion by temporary coatings of grease, paint, or other preservative. Such temporary coatings are removed shortly before use of the component. A cleaning

method is selected based on the type of preservative to be removed.

Installation Cleaning

Installation activities (construction, repair, modification) represent opportunities for introducing contaminants into a clean item. These activities are controlled in order to minimize the contamination of cleaned items and to perform cleaning operations as necessary as installation progresses. Typical controls consist of good work practices, sealing openings, prohibition of deleterious materials, and cleaning at completion of the work.

- work practices - Operations which have potential for contaminating components include welding, grinding, sanding, chipping, wire brushing, sawing, painting, and grit blasting. These operations can internally contaminate the affected component or adjacent components. Highest potential for contamination exists when there are exposed crevices, blind holes, dead legs, undrainable cavities, and inaccessible areas. In such cases, work practices are planned to avoid contaminating the components. These practices include:
- orientation of the work such that chips, spray, or other contaminants fall away from the area of concern.
- temporarily covering areas of concern with tarpaulins or other protective materials.
- masking areas of concern.
- sealing - Aside from temporary sealing of openings during performance of a particular installation activity, openings in components and pipe ends are sealed at all times except when the specific work activity requires removal of the seals. In addition, fitted weld joints, which are not immediately welded,

are wrapped in polyethylene or other non-halogenated plastic until welding is performed. These sealing practices ensure protection from internal contamination regardless of the nature of work in the vicinity.

- prohibition of deleterious materials - Corrosion resistant alloys (stainless steel and nickel base alloys) are susceptable to stress corrosion cracking when subjected to stress, temperature, and low melting alloys or halogens. By avoiding contamination with low melting alloys and halogens, stress corrosion cracking is avoided. Accordingly, low melting alloys and halogens are prohibited from use during installation activities. This means that marking materials, seals, hammers, paints, preservatives, and other materials used on corrosion resistant alloys cannot contain the prohibited materials. Such items are procured and certified as acceptable based on their not containing low melting alloys such as lead, sulfur, zinc, and mercury, and not containing leachable halogens. In this manner, contact of corrosion resistant alloys with deleterious materials is avoided.
- cleaning at completion of installation - Installation activities consist of a number of "work segments" with each segment constituting a desired and manageable increment of work. A "job package" is prepared for each segment. The job package contains necessary instructions, drawings, and procedures to accomplish the work. The final step of the instructions for each job package requires leaving the installation in an acceptably clean condition. At this step, soils introduced by the work are removed by an acceptable cleaning method and seals are placed on openings and pipe ends. In this manner, components are left

in the prescribed cleanness condition and protected from future contamination.

Maintenance of Installation Cleanness

After each component and piping system is installed, some time may elapse prior to connecting all openings with their interfacing components or piping. As previously described, installed components and piping systems are left clean and sealed by the installation activity. Two basic controls are used to ensure such cleaned and sealed items remain clean. First, the quality control activity periodically monitors for integrity of seals and for compliance of work activities with the instructions of the job package. Second, job packages for work activities which require opening of installed seals contain special instructions for maintaining cleanness. Typically, these special instructions include (1) cleaning of the surrounding area prior to opening a seal, (2) clean outer clothing and shoe covers for personnel who must enter the cleaned system, (3) recleaning interior surfaces upon completion of the work, and (4) resealing remaining openings and pipe ends.

Preoperational Cleaning

Preoperational cleaning ensures that a system is in a specified state of cleanness prior to designating that system as ready for operation. Preoperational cleaning is accomplished by flushing the system with water or a cleaning solution, dependent upon the degree of cleaning activities during installation activities. If each installation activity complied with the cleaning and cleanness controls previously described, water flushing is sufficient. However, if internal surfaces were not cleaned and maintained clean, flushing with a cleaning solution is necessary. Flushing with a cleaning solution is followed

by a water flush to remove the cleaning solution. It is typically more economical to control cleanness of large components and large diameter piping during installation such that only a water flush of the installed system is necessary. Two principle sources of contamination which may require flushing with a cleaning solution are oil from air tools and oxide films on internal surfaces in systems which require removal of internal rust.

Each type of flushing requires specific preparations for accomplishing the flush. In this regard, consideration is given to other plant activities, personnel readiness, circulating flow paths, component protection, and water quality.

- other plant activities - Cleaning and flushing operations are scheduled to minimize interference from other plant operations. Either installation activities or tests of other system may require use or isolation of the system to be flushed. In such instances, flushing is delayed until a "time window" exists where the system is dedicated to the flushing activity. During the flush, coordination with installation activities is necessary to preclude violation of cleanness of the system by nearby installation activities.
- personnel readiness - Flushing is typically the first activity which operates the system as a whole. Personnel must be familiar with system operation and location of system components and control devices. In addition, whenever cleaning agents are used, personnel must be familiar with the use and associated safety precautions of the cleaning agent. Finally, personnel must be familiar with the flushing procedure. Training of personnel in these areas is conducted in advance of flushing operations to

permit timely accomplishment of flushing within the alloted "time window".

- circulating flow paths - The actual flow path of the flush is carefully established and checked to ensure adequate flushing. This is normally accomplished by the preparer and reviewer of the flushing procedure. The established flow path must be consistent with requirements of system specifications. Dead legs (such as vent, drain, and instrumentation lines) are identified and special provision is made for their flushing. All components and component controls which must not be actuated during the flush are identified and tagged. Tags are normally red in color and state "Danger - Do Not Operate".
- component protection - Components which may be damaged by the flush are blanked off, bypassed, or removed. Examples of such components are demineralizers, filters, certain instruments, and internals of certain valves. Screens are installed on pump suctions. Ideally, all systems are flushed prior to installing reactor internals and control rods. But in the event flushing is necessary after installation of reactor internals, flushing is either away from the reactor vessel or particulate filters are installed. Finally, provisions are made to collect leakage and the flushing discharge in order to prevent wetting of thermal insulation and electrical components.
- water quality - An ample supply of water of necessary quality must be on hand for water flushing or for flushing to remove cleaning agents. The quality of the flushing water is required to equal the quality required for system operation. Where system operating water quality is not specified, engineering

selects either "fresh water" or "demineralized water: for the flush. (demineralized water is equivalent to that specified for reactor coolant systems). Water quality limits for fresh and demineralized water are listed in Table 30-5-11.

Table 30-5-11. Water Quality Requirements

Element	Water	
	Fresh	Demineralized
pH at 25°C	5.5 to 8	5.5 to 8
Chloride	< 100 ppm	< 1 ppm
Fluoride	< 5 ppm	< 1 ppm
Sulfide	< 1 ppm	< 1 ppm
Total Dissolved Solids	< 500 ppm	not applicable
Turbidity	< 5 Jackson Units	< 1 Jackson Unit
Silica	not applicable	< .05 ppm
Conductivity	not applicable	< 3 μmho/cm

Each flushing operation is performed in accordance with a written procedure or instruction. Flushing may be with water, alkaline cleaning solutions or chelating agents as necessary.

Flushing with water is typically adequate if the intended level of cleanness was maintained during installation. Key elements of water flushing are (1) confirmation of completion of necessary preparations, (2) use of water of required quality, (3) velocity of flush equal to system design velocity or other specified value, (4) provision for acceptance of flushing by filter, turbidimetric, or chemical analysis, (5) provision for flushing dead legs upon completion of the system flush, and (6) provision for system sealing or layup after the flush.

Flushing with alkaline cleaning solutions is used

when systems are known or suspected to contain oil residues or other organic soils not readily removable by water flushing. Alkaline cleaners, such as trisodium phosphate, are selected which do not contain free caustic. Emulsifiers and wetting agents may also be used if heavy organic soils are present. Key elements of alkaline cleaning flushes are (1) confirmation of completion of necessary preparations, (2) use of specified cleaner and concentration, (3) heating of the alkaline cleaning solution to the specified temperature, (4) provision for determining adequacy of cleaning (typical methods are examination of a known soiled area or use of a test coupon contaminated with the expected soils), (5) water flushing upon completion of alkaline cleaning including flushing of dead legs, and (6) provision for sealing the system or placing it in layup.

Flushing with chelating agents is used when light corrosion product films must be removed from carbon and low alloy steels. However, this method is not suitable for sensitized stainless steel or nickel base alloys. (Sensitization of stainless steel refers to chromium-carbide precipitation to grain boundaries. Acid cleaning attacks carbides). In addition, entrapment of acids in crevices and contact of acids with nonferrous materials is avoided. Key elements of chelate cleaning are (1) confirmation of completion of necessary preparation, (2) use of specified acid-chelate solution, (3) complete removal of the acid-chelate solution by draining, water flushing, and a neutralization flush, and (4) system sealing or layup.

Layup

Upon completion of preoperational cleaning, the system may be released for preoperational testing such as hydrostatic testing. In such event, the next test takes con-

trol of the system and its condition. However, the cleaned system may rest idle for some time period prior to pre-operational testing. In such event, the system is placed in layup.

Layup is a condition in which an idle system is placed to protect that system from oxidation and entry of contaminants. It maintains system cleanness subsequent to preoperational cleaning.

Either dry or wet layup is used. Dry layup is the condition obtained by filling the system with a dry, inert gas. Either nitrogen or the system operating gas for gas systems are used. Wet layup is the condition obtained by filling with water of specified quality or with the operating liquid for liquid systems.

For either dry or wet layup, initial filling includes venting of all high points to remove air. Also, the system is moderately pressurized and system pressure is monitored to maintain the layup condition.

When water is used for wet layup, chemical treatment is normally made to control pH and to scavenge dissolved oxygen. Hydrazine-morpholine treatments are common where hydrazine scavenges oxygen and morpholine controls pH. Where treated water is used, periodic tests are made to determine the need for chemical additions. Also, at the conclusion of the layup period, the treated water is drained and the system is filled with its operating fluid.

Housekeeping

Integral with the foregoing activities, housekeeping procedures are established at the nuclear power plant site to control the general cleanness of designated areas within the plant. Housekeeping procedures define area zones and establish controls within each type of zone for controlling cleanness. Five types of zones are established

as follows:

- Zone I - Zone I Areas require the highest order of cleanness. These areas are equipped with a clean clothing change facility at the vestibule or entrance, preferably with toilet facilities immediately adjacent so that personnel working in the controlled area do not have to wear the special clothing in other areas. Such areas provide for complete outer change of clothing by personnel, including use of shoe covers, head covers, and gloves to protect all equipment surfaces from outside contamination. Material entering this zone is appropriately cleaned prior to entry.
- Zone II - Zone II Areas have intermediate cleanness requirements less restrictive than Zone I but are areas where foreign matter may have detrimental effects.
- Zone III - Zone III Areas are less restrictive than Zones I and II but require access control over personnel and materials.
- Zone IV - Zone IV Areas are those where it is desired to regulate the use of tobacco and eating for material and equipment protection or for health and fire hazards.
- Zone V - Zone V Areas are unrestricted construction areas requiring good construction site housekeeping practices only.

For each type of area, written procedures delineate the responsibilities and techniques for maintaining cleanness at the desired level. For Zones I, II and II, the procedures require a written record (e.g., logbook) of the entry and exit of all personnel and material. In general, these procedures require the elements of control listed in Table 30-5-12.

Table 30-5-12

Control Elements for Housekeeping Zones

Element	Zones				
	I	II	III	IV	V
Clothing change	Yes	No	No	No	No
Clean gloves, shoe covers, head covering	Yes	Yes	No	No	No
Filtered air	Yes	No	No	No	No
Material precleaning	Yes	No	No	No	No
Material accountability	Yes	Yes	Yes	No	No
Personnel accountability	Yes	Yes	Yes	No	No
No use of tobacco or eating	Yes	Yes	Yes	Yes	No

GLOSSARY OF TERMS

- Acid Cleaning - The removal of metal oxides by either dissolution of the oxide or undercutting the oxide by dissolution of the base metal with an acid solution.
- Alkaline Cleaning - The removal of organic contaminants by converting them to an emulsion with an alkaline solution such as trisodium phosphate.
- Chelate Cleaning - The removal of slightly soluble compounds such as iron oxide, by complexing the metallic ions with organic chelating compounds such as ethylene diamine tetra-acetic acid (EDTA).
- Chemical Conditioning - The addition of chemicals in low concentration to flush, rinse, or layup water to prevent precipitation of dissolved solids, inhibit corrosion, etc.
- Cleaning - The removal of any contaminants that might have a deleterious effect on plant safety and

reliable operation.

- Contractor - Any individual or organization entering into a contract to furnish items or services to a purchaser. The term contractor includes the terms Vendor, Supplier, and Subcontractor or sub-tier levels of these where appropriate.
- Contamination - Any undesirable foreign material on the surface of an item, in the atmosphere, or in process liquids or gases.
- Corrosion Resistant Alloys - Materials, such as stainless steel, nickel-base, or cobalt-base alloys, that inherently resist oxidation or chemical attack in water, air, and the operating environment.
- Crevice - Any narrow opening in a surface or any open juncture between mating surfaces in which solutions can be trapped and not readily removed during rinsing or flushing operations; for example, the annular spaces in threaded connections and socket assemblies, tube-to-tube sheet joints, and tube-to-tube support joints.
- Dead Leg - Any area that does not have flow during the cleaning operation or which cannot be drained without special provisions.
- Documentation - Any written or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures or results.
- Flushing - Flowing water through a component or system at adequate velocity to suspend and carry away anticipated contaminants.
- Inhibitor - A chemical additive which retards some specific chemical reaction.
- Inaccessible Area - An area or opening in an item which is not directly accessible for cleaning or inspection.

- Item - Any level of unit assembly, including structure, system, subsystem, subassembly, component, part or material.
- Layup - The protection of an item after it has been cleaned, to prevent corrosion of interior surfaces while the item is out of service or awaiting subsequent operations.
- Mechanical Cleaning - A method in which contaminant removal is accomplished solely by mechanical means, including wiping, abrasive blasting, brushing, grinding, sanding, chipping, etc.
- Pitting - Localized corrosion resulting in surface defects.
- Purchaser - The agency responsible for issuance and administration of a contract, subcontract, or purchase order imposing a standard or portions thereof.
- Rinsing - (1) Filling and draining an item with water until contaminants in the effluent water are reduced to some predetermined concentration, or (2) flowing water through the system or component at low velocity until contaminants in the effluent water are reduced to some predetermined concentration.
- Rust - Corrosion products, consisting largely of iron oxide. Such oxides may vary in color from red to black and may form a loosely adherent heavy covering to a tightly adherent light film. Pitting or general surface roughening may or may not be present.
- Sensitized Corrosion Resistant Alloy - Any alloy which has been subjected to heating that causes intergranular precipitation of chromium carbides in quantities sufficient to be detected by methods of ASTM A262-68, Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steel.
- Solvent Cleaning - Dissolving organic contaminants with an organic solvent.

EXERCISES

This check list summarizes the major points of this module. Put a check by each point as you recall it.

____ Solvent cleaning is a process for removing organic soils with an organic solvent. The cleaning method may be by wiping, immersion or spraying, with or without vibration of the part. It is typically used for smaller parts and for hand cleaning of large parts.

____ Emulsion cleaning is a process for removing organic soils with an emulsified solvent-aqueous medium. It is mostly used by suppliers when superficial cleaning is sufficient and when a light film of residual oil is desired or not objectionable.

____ Acid cleaning is a process for removing inorganic and organic soils with an acid. Inhibitors are used to reduce the amount of attack on metals and for spray systems, antifoaming agents are added to reduce foaming. Methods of acid cleaning include wipe on-wipe off, spraying, immersion, barrel, and electrolytic. Any acid cleaning process etches the part to some degree. It is generally used when inorganic soils must be thoroughly removed.

____ Acid pickling is a more severe acid cleaning process. It uses immersion techniques and is most efficient for removal of scale. It is generally used when bright metallic finish is required.

____ Chelating is a form of acid cleaning which uses chelating agents. Chelates accelerate cleaning of lubricants containing metallic ingredients by reacting with the metal ions. It is generally used for cleaning of piping systems.

____ Vapor degreasing is a cleaning process which uses hot vapors from a chlorinated solvent to remove organic soils. Four methods are available: vapor phase,

vapor-spray-vapor, warm liquid-vapor and boiling liquid warm liquid-vapor. Ultrasonic vibration may be used for small parts. It is generally used for cleaning oily parts, particularly those with crevices.

____ Abrasive blast cleaning is a method of removing organic and inorganic soils by the forceful impingement of abrasive particles against a surface. Dry or wet blasting techniques are available. Some peening and cutting of the surface occurs with abrasive blasting. It is generally used for removing scales and coatings.

____ Salt bath descaling is a method of removing tight-adhering scale from nickel and cobalt base alloys. It may use reducing, oxidizing, or electrolytic processes. It is generally used by material suppliers to clean final material forms.

____ Alkaline cleaning is a method of removing organic and inorganic soils by detergent cleaning. Soak, spray, or electrolytic processes may be used. It is generally used by material and component suppliers for removing oily soils and light rusts.

____ Component cleanness acceptance criteria is that associated with the cleanness classification of the system which receives the component. Four classification levels are established.

____ Cleanness classification levels and their associated acceptance criteria are:

Classification	Acceptance Criteria
Class A	No evidence of contamination
Class B	Clean appearance except for scattered rust, no particulate contaminants, no organic films or contaminants, acceptable to cloth wipe or flushing filter tests.

Class C	Same as Class B except that surfaces may have thin uniform rust films on carbon steel, scattered areas of rust on corrosion assistant alloys, and rust staining on flushing filters.
Class D	Nominal cleanness. Acceptable conditions are tightly adherant scale on carbon steel, coatings without flaking or peeling, adherent rust films, and acceptable flushing test results.

____ Preinstallation cleanness controls ensure that components to be installed are clean. Procurement documents specify the cleanness conditions to be met by materials and product. Receipt inspection confirms compliance and storage facilities maintain cleanness. Temporary preservatives are not removed until shortly before installation of the item.

____ Installation cleaning activities minimize introduction of soils and accomplishes necessary cleaning operations as installation progresses. Installation cleaning activities include work practices which foster cleanness, use of seals, prohibition of deleterious materials and cleaning operations as necessary at completion of installation.

____ Maintenance of installation cleaning preserves the established degree of cleanness. Between installation and flushing, cleanness of components and systems is maintained by seals and special controls when seals must be opened. The special controls include cleaning the surrounding area, use of protective clothing, recleaning interior surfaces upon completion of work and resealing.

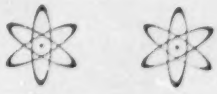
____ Preoperational cleaning is accomplished by water flushing unless soils are present which require other cleaning methods. When other cleaning is necessary, alkaline flushing is mostly used although acid-chelating agent flushing may be necessary to remove rust films.

____ Specific preparations are necessary for flushing. These preparations include scheduling a "time window", training personnel, establishing the flushing paths and component protective measures to be used, and ensuring availability of ample water of necessary quality.

____ Alkaline or chelate flushing is followed by water flushing to remove the cleaning agents.

____ Unless the system is released to other tests, each system is placed in layup after flushing. Layup means filling the system with its operating fluid or with water or nitrogen. Wet layup with water normally includes chemical treatments to control pH and to scavenge oxygen. Hydrazine is used to scavenge oxygen and morpholine is used to control pH.

____ Housekeeping refers to the establishment of area zones, cleanliness requirements for each zone and procedures for entry and exit of persons and material.

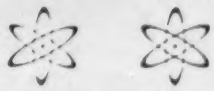


MATERIALS

The following materials are required to support this module if the optional activities for turbidity and titration-analyses are used:

1. Jackson Candle Turbidimeter Kit
2. Plastic tubing
3. Rubber bulb siphon

4. Assorted beakers
5. One or more sources of water
6. Distilled water
7. Laboratory reagents of sodium hydroxide, sulfuric acid and any other acid.
8. Assorted burettes
9. Burette stands and clamps
10. Glass stirring rods



PROCEDURES

The following activities reinforce the information presented in this module:

1. Determine if the acceptance criteria as given by this module, have been met. For each of the following product descriptions, list each condition of noncompliance and a method of cleaning which will remove each condition of noncompliance.
   a. Receipt inspection examines carbon steel flanged pipes and elbows destined for a Class C system. The faces of five flanges exhibit light rust which is partially removed by light brushing. Interior walls appear clean except for rust films which are not removable by brushing. Eighteen of the flange through holes (for bolting) exhibit rust which is flaking.

b. Preoperational water flushing of a Class B stainless steel system exhibits the following upon first inspection of the flushing filter: no rust staining, three minute particles of about 1/64 inch diameter, a paper strip 1 by 2 inches, four metallic slivers the smallest of which is 1/32 inch width by 1/4 inch long.

c. A six inch motor operated carbon steel gate valve is withdrawn from site stores for installation into a Class C system. Visual Inspection determines that a tight rust film is exhibited throughout the valve internals. In addition, a spot of loose rust measuring 1/2 by 1 inch is found on the weld and preparation on the inlet nozzle.

d. A 1/2 inch stainless steel manual globe valve is withdrawn from site stores for installation into a Class B system. Visual inspection reveals: lint on the inside diameters of inlet and outlet nozzles and oil residue adjacent the seat.

e. A Class C system is flushed with water. Initial inspection of the flushing filter exhibits rust spackling and considerable oil stains. No particulates other than rust spackling are present.

f. A length of carbon steel pipe is visually inspected upon receipt. The pipe is intended for the fire main header. Interior surfaces of the pipe exhibit flaking scale.

g. A visual inspector enters a storage tank of a Class B system after installation and flushing of the tank. The inspector observes: metallic chips, in the bottom of the tank, adherent discolorations on each welded joint, and six areas of loose rust. The areas of rust are widely separated and measure 1/2 x 1, 1/2 x 2, 2 x 2, 1 x 2, 1 x 3, and 1/4 x 1/2 inches.

2. Perform a Jackson Turbidity Test (Optional Activity)
   a. Assemble the following equipment: (1) Jackson Candle Turbidimeter (consists of graduated glass tube, a standard candle, a light shield around the tube, and a support for the candle and tube), (2) plastic tube and rubber bulb siphon, (3) assorted beakers, (4) sample water for test from one or more sources.
   b. Mount the turbidimeter in the vertical position such that the centerline of the graduated tube passes through the centerline of the candle.
   c. Darken the room for all observations.
   d. Enclose the graduated tube with its light shield.
   e. Light the candle and pour sample water into the graduated tube until the candle flame is no longer visible.
   f. Siphon sample water from the graduated tube until the candle flame becomes visible.
   g. Extinguish the candle flame.

h. Read the Jackson turbidity units at the level of the sample.

3. Perform a Titration Method of chemical analysis (Optional Activity):

a. Prepare a dilute solution of sodium hydroxide by adding 30 milliliters of the laboratory reagent to 120 milliliters of distilled water. Mix thoroughly by stirring. Do not contaminate or dilute this solution in any way as it will be used throughout this experiment.

b. Obtain two burettes from the instructor, one for the acid and one for the base. Rinse both burettes twice with water.

c. Drain the water and rinse one of the burettes with two small portions of the sodium hydroxide solution you have prepared. Fill the burette with sodium hydroxide solution.

d. Obtain 100 milliliters of a standard solution of sulfuric acid from the instructor. The normality of this solution will be given to you.

e. Rinse, drain, and fill the second burette in the same manner with the acid solution.

f. Clamp the burettes to the burette stand and fill the tip of each burette by opening the stopcock momentarily and letting a small amount of the solution flow through the tip into the beaker containing that solution.

g. Read the level of the solution in each burette by lining your eye with the bottom of the miniscus. Read the burette to the nearest 0.01 milliliter. Record these values on the data sheet.

h. To standardize the base solution, draw approximately 15 milliliters of the standard acid solution into a small beaker.

i. Add 2 drops of phenophthalein solution to the acid.

j. While constantly stirring, slowly add approximately 3 to 4 milliliters of the base from the burette.

Note: As the base hits the acid, a red color forms, but disappears quickly on stirring. To make the color change easier to see, place a piece of white paper under the beaker.

k. With constant stirring, slowly add more base solution until one drop produces a permanent pink color in the solution. This color should persist for at least 30 seconds.

Note: If too much base is accidentally added, add more acid until the solution is again colorless. Titrate again until one drop produces the permanent pink color change.

l. To insure that none of the solution has adhered to the sides of the beaker and the stirring rod, wash them down with distilled water using a wash bottle.

m. Read the burettes. Record the readings on the data sheet.

Note: Wait about one minute prior to taking the burette readings to allow for any drainage in the burettes.

n. Repeat steps of the experiment starting with about 20 milliliters of acid. Record burette reading on the Data Sheet. From the data obtained, calculate the normality of the base you prepared. Record calculations on Data Sheet. (milliliters of base) (Normality of base) = (milliliters of acid) (Normality of acid) Use this formula for your calculations.

o. Obtain, from the instructor, an unknown acid solution whose concentration you are to determine.

The base you prepared and standardized is to be used as the standard solution in this titration. Record the data as before on the data sheet. Calculate the Normality of the unknown. Be sure to record the number of your unknown.

p. Give data sheet to instructor

DATA TABLE

Table 30-5-13

Data Sheet for Titration

	Standard Acid	Base
Final Burette Reading	_____ ml	_____ ml
Initial Burette Reading	_____ ml	_____ ml
Volume of Solution	_____ ml	_____ ml
Final Burette Reading	_____ ml	_____ ml
Initial Burette Reading	_____ ml	_____ ml
Volume of Solution	_____ ml	_____ ml

Normality of NaOH Solutions Run#1 _____ N Run#2 _____ N

Unknown Sample

	Standard Base	Acid
Final Burette Reading	_____ ml	_____ ml
Initial Burette Reading	_____ ml	_____ ml
Volume of Solution	_____ ml	_____ ml
Final Burette Reading	_____ ml	_____ ml
Initial Burette Reading	_____ ml	_____ ml
Volume of Solution	_____ ml	_____ ml

Normality of Unknown Acid Solution Run #1 _____ N Run #2 _____ N

Average _____ N

Number of Unknown Sample _____

Instructor Review _____ Date _____

Calculations

REFERENCE MATERIALS

NRC, Regulatory Guide 1.37, Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water Cooled Nuclear Power Plants, Nuclear Regulatory Commission, Washington, D.C., 1973

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ASME, ANSI N45.2.1, Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants, American Society of Mechanical Engineers, New York, N.Y., 9173

ASME, ANSI N45.2.3, Housekeeping During the Construction Phase of Nuclear Power Plants, American Society of Mechanical Engineers, New York, N.Y., 1973

ASM, Metals Handbook, Volume 2, American Society for Metals, Metals Park, Ohio, 1964

ASTM, Annual Book of ASTM Standards, Part 31, American Society for Testing and Materials, Philadelphia, PA 19103, 1978

TEST

1. Briefly describing the following cleaning methods including the types of soils removed and its general application.

   a. Solvent Cleaning

   b. Emulsion Cleaning

   c. Acid Cleaning

   d. Acid Pickling

   e. Chelating

   f. Vapor Degreasing

   g. Abrasive blast cleaning

h. Salt Bath Descaling

i. Alkaline Cleaning

2. Define:

a. cleaning

b. contamination

c. crevice

d. dead leg

e. flushing

f. inaccessible area

g. layup

3. Name four cleanness classification levels and briefly describe the degree of cleanness associated with each level.

Classification	Degree of Cleanness
a.	
b.	
c.	
d.	

4. State the purpose of each of the following cleanness control activities.

a. Preinstallation cleanness

b. Installation cleaning

c. Maintenance of installation-cleaning

d. Preoperational cleaning

e. Layup

f. Housekeeping

5. Briefly describe how each of the following cleanness control activities is accomplished.

   a. Installation cleaning

   b. Preoperational cleaning

   c. Wet layup

6. Briefly describe typical preparations for flushing which are associated with:

   a. other plant activities

   b. circulating flow paths

   c. component protection

   c. water quality

7. Describe typical water treatment used for wet layup.